# PRICE DISCOVERY AND INTEGRATION OF THE PEANUT MARKETS IN THE UNITED STATES

An Undergraduate Research Scholars Thesis

by

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# ABSTRACT

Price Discovery and Integration of the Peanut Markets in the United States

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Currently, the United States is a major supplier in the world peanut market. Using grower level monthly peanut price data from 1982-2018, this study estimates market integration and price discovery patterns among grower level peanut prices from Alabama, Florida, North Carolina, Georgia, Texas and Virginia, using causality structures identified through cutting-edge machine learning algorithms that are applied to the variance-covariance matrix of peanut prices. These causality structures are developed using Directed Acyclic Graphs. Preliminary analysis shows that Georgia is a price leader and others are followers in the current and lag time. Also, price of peanuts in Texas and Georgia are important in determining peanut price of other markets such as North Carolina, Virginia and Alabama. Findings from this study are expected to be useful for peanut producers and marketers as well as government policy makers to design national/state level peanut marketing programs.

Key Words: Peanut prices, market integration, price discovery, directed acyclic graphs, machine learning

# CHAPTER I

# INTRODUCTION

The United States is among the significant suppliers in the world peanut market, with China and India being the largest. Other major peanut producing countries include Senegal, Sudan, Brazil, Argentina, South Africa, Malawi and Nigeria (Virginia Carolinas Peanuts, 2018). In the United States, 99% of peanuts are grown in ten states. Georgia grows about 50% of U.S. peanuts. Others are Texas (10%), Alabama (10%), Florida (9%), South and North Carolina (14%), Mississippi, Virginia, New Mexico and Oklahoma (American Peanut Council, 2018). According to National Agricultural Statistical Service (NASS) of United States Department of Agriculture (USDA), price received for peanuts by farmers at the farm-gate level is $0.23 per pound. This is a national average as of June 2018. Peanut prices vary by state. As a result, it is likely that peanut price discovered in one state potentially affects the price discovery process of another state, given the proximity of aforementioned peanut producing states in the United States. Information with regards to peanut market integration and price discovery patterns, if any, would be useful not only for peanut producers in the United States, but also for peanut marketing and promotion entities, such as National Peanut Board.

The U.S. peanuts market has an annual market value of over 1 billion dollars and with 10 southern states producing the majority of U.S. peanuts, the peanuts market has a significant economic impact on these states. There are many different factors, such as production regions of the types of peanuts, agricultural policies, and the global market, that are important for understanding the peanuts market and price relationship among states.

Runner, Virginia, Spanish, and Valencia are the four main types (varieties) of peanuts grown in the United States. Runners, which are mainly used for peanut butter, are grown in Georgia, Alabama, Florida, Texas, and Oklahoma. Sold as salted peanuts or roasted, Virginia type peanuts are grown in southeastern Virginia, northeastern Carolina, and west Texas. Oklahoma and Texas are responsible for most of the production of Spanish-type peanuts. This variety is used in peanut candy, salted nuts, and peanut butter. Valencias are mainly grown in New Mexico and are roasted and sold in the shell and are used for boiled peanuts. Runners account for 80% of U.S. production, while Virginias account for 15%, Spanish make up 4%, and Valencias account for less than 1% of total U.S. production (American Peanut Council). Peanuts for edible use account for the majority of peanut consumption in the U.S. However, other uses include peanut oil, seed, and feed (Customs and Border Protection, 2008).

Until 2002, peanuts were sold under a marketing quota system which guaranteed producers, who had quota rights, a high price on a "government-established 'quota loan rate' of $610 per ton (during 1996-2001)" (Dohlman, Hoffman, Young & McBride, 2004). Producers without quota rights exported their peanuts at world prices, which were much lower than the quota loan rate prices. Import restrictions were also a component of the marketing quota system. However, (North American Free Trade Agreement) NAFTA and (World Trade Organization) WTO agreements opened the peanuts market through tariff rate quotas. These trade agreements, and opposition from consumer groups and peanut processors, contributed to the demise of the marketing quota system (Dohlman et al., 2004). The marketing quota system ended with the 2002 Farm Act. This Act allowed peanut producers to receive marketing assistance loans, fixed direct payments, and counter-cyclical payments. These forms of government assistance had been available to grain, oilseed, and cotton producers.

In the years directly following the passage of the 2002 Farm Act, farm-level prices and total U.S. plantings decreased. Major peanut producing states in the southeast, such as Georgia and Florida, had stable or increased planted acreage. However, many other states, in particular Virginia, Texas, and Oklahoma, had large decreases in planted acreage (Dohlman et al., 2004). Despite these changes, U.S. peanut consumption in 2003-2004 rose at a record rate of 9 percent. Changes in prices, market promotion, and dietary preferences are contributing factors to changes in demand (Dohlman et al., 2004). Bolotova (2018) found that from 2002 to 2016, yearly average area harvested decreased 13%, yearly average yield increased 37%, and yearly average peanut price decreased 22%, when compared to 1980 to 2001.

Following the end of the marketing quota system, peanut producers managed risk by "increasing their use of marketing contracts to lock in prices and by maintaining a diversified commodity mix to spread risk" (Dohlman, Foreman & Da Pra, 2009). Non-quota holders primarily used marketing contracts prior to the policy change, with the end of the quota program the percentage of producers using marketing contracts rose from 40 percent in 2002, to 65 percent in 2007 (Dohlman et al., 2009). The end of the quota system resulted in producers having less of a bargaining position with shellers. Without the minimum support price that was set under the quota system, shellers were no longer willing to "contract at the support price" (Smith and Wolfe, 2004). According to Adjemian (2016), "The typical contract has a one-year term, and processors make take-it-or-leave-it offers to farmers for a price equal to the US Department of Agriculture (USDA), Commodity Credit Corporation's (CCC) loan rate plus a premium." In addition, the peanuts market is a relatively thin market with no futures or cash market and only two companies processing 70% of U.S. peanuts (Adjemian et al., 2016). These two companies are Birdsong Peanuts and Golden Peanut Company, each operate 6 peanut processing facilities

and over 80 buying points throughout the U.S. peanut growing region. Ultimately, the end of the marketing quota system had a profound effect on how prices were determined.

Taking the factors that have shaped to peanuts market into consideration, the general objective of this study is to discover market integration and price discovery patterns in major peanut producing states in the United States. Specific objectives are to determine: (i) patterns in peanut prices from 1982 through 2018 at grower level in major peanut producing states in the United States delineated by before and after the discontinuation of the price quota system, (ii) correlations in peanut prices across states for these periods, and (iii) peanut market integration and price discovery patterns across the states using cutting-edge machine learning algorithms (such as use of Directed Acyclic Graphs) for before and after the discontinuation of the price quota system.

# CHAPTER II

# DATA

Data used in this study are from the United States Department of Agriculture National Agricultural Statistics Service (USDA-NASS). This data consisted of the monthly price received, which was measured in dollars per pounds, for 6 states from 1982 through 2018. The 6 states consisted of Georgia, Alabama, Texas, Florida, North Carolina, and Virginia. While other states such as Arkansas, Mississippi, New Mexico, South Carolina, and Oklahoma also produce peanuts these states were omitted because of inconsistencies in data. The summary statistics for the data used are shown in Table 1.

Table 1. Summary Statistics- Monthly Peanut Prices, $/lb..

| | AL1 | AL2 | FL1 | FL2 | GA1 | GA2 | NC1 | NC2 | TX1 | TX2 | VA1 | VA2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Median** | 0.274 | 0.198 | 0.254 | 0.198 | 0.273 | 0.202 | 0.281 | 0.236 | 0.268 | 0.241 | 0.278 | 0.227 |
| **Mean** | 0.273 | 0.205 | 0.257 | 0.209 | 0.270 | 0.212 | 0.280 | 0.243 | 0.270 | 0.257 | 0.274 | 0.231 |
| **Std Dev** | 0.061 | 0.043 | 0.050 | 0.040 | 0.054 | 0.045 | 0.051 | 0.048 | 0.056 | 0.079 | 0.047 | 0.050 |
| **Min** | 0.126 | 0.136 | 0.145 | 0.154 | 0.141 | 0.113 | 0.168 | 0.142 | 0.180 | 0.102 | 0.167 | 0.097 |
| **Max** | 0.586 | 0.360 | 0.455 | 0.360 | 0.547 | 0.355 | 0.463 | 0.374 | 0.520 | 0.565 | 0.391 | 0.354 |

Note: States denoted with a '1' represent the time period with quota system, 1982 to 2001. '2' represents the time period with contract pricing system, 2002 to 2018. AL=Alabama, FL=Florida, GA=Georgia, NC=North Carolina, TX=Texas and VA=Virginia

The end of the quota system in 2002 drastically changed the peanuts market and how prices were determined. Due to this difference the data was split into two time periods, 1982 to 2001 and 2002 to 2018. A statistical *t*-test and *F*-test was conducted to determine the difference between the mean and variability of these prices between periods 1982-2001 and 2002-2018, respectively. Hypothesis testing functionality of SIMETAR statistical software was used to conduct these tests. 0.05 cut-off p-value was used to test the statistical significance in this study.

The results from this test based on p-value 0.05, which are exhibited in Table 2, suggest that there is a clear difference between price patterns before and after the policy change for the majority of states studied. However, this test fails to reject that the means are different between the two time periods in Texas and also fails to reject that the variances are different in North Carolina and Virginia. Despite this for Texas, the hypothesis that the variances of the two time periods are equal is rejected. The 2-sample t test also rejects the hypothesis that North Carolina and Virginia mean from the two time periods are equal. Ultimately, these tests confirm that there is a significant difference between prices in the two time periods for the majority of the peanut producing states.

Table 2. Results from t-Test and F Test of mean peanut price and variance of price series between time periods, 1982-2001 and 2002-2018

| | | **Calculated Value** | **Critical Value** | **P-Value** | **Results from the Hypothesis Test** |
|---|---|---|---|---|---|
| AL | 2 Sample t Test | 10.21 | **2.26** | 0.000 | Reject the null hypothesis that the Means are Equal |
| | F Test | 2.06 | **1.32** | 0.000 | Reject the null hypothesis that the Variances are Equal |
| FL | 2 Sample t Test | 8.45 | **2.26** | 0.000 | Reject the null hypothesis that the Means are Equal |
| | F Test | 1.59 | **1.32** | 0.003 | Reject the null hypothesis that the Variances are Equal |
| GA | 2 Sample t Test | 9.57 | **2.26** | 0.000 | Reject the null hypothesis that the Means are Equal |
| | F Test | 1.44 | **1.32** | 0.016 | Reject the null hypothesis that the Variances are Equal |
| NC | 2 Sample t Test | 6.12 | **2.26** | 0.000 | Reject the null hypothesis that the Means are Equal |
| | F Test | 1.13 | 1.32 | 0.233 | **Fail** to Reject the null hypothesis that the Variances are Equal |
| TX | 2 Sample t Test | 1.66 | 2.25 | 0.099 | **Fail** to Reject the null hypothesis that the Means are Equal |
| | F Test | 2.02 | **1.34** | 0.000 | Reject the null hypothesis that the Variances are Equal |
| VA | 2 Sample t Test | 7.45 | **2.26** | 0.000 | Reject the null hypothesis that the Means are Equal |
| | F Test | 1.12 | 1.34 | 0.262 | **Fail** to Reject the null hypothesis that the Variances are Equal |

Note: Significance level considered is p-value 0.05 AL=Alabama, FL=Florida, GA=Georgia, NC=North Carolina, TX=Texas and VA=Virginia

The data also contained some missing values, if 5 or less values in a row were missing then a random walk model was used to forecast these values. If more than 5 values were missing, then those values were forecasted using appropriate autoregression estimates for each series. This was conducted using SAS statistical software. Figures 1 through 6 illustrate the price patterns for each individual state, the dashed line illustrates where the data was split and the rectangular box highlights the data points that were forecasted.

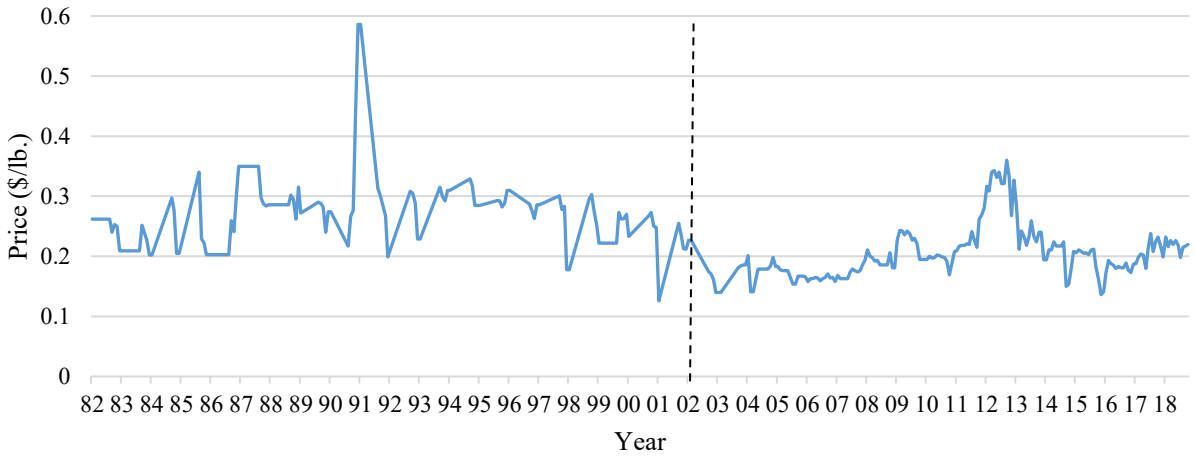


Figure 1. Alabama Monthly Peanut Price Recieved, 1982- 2018

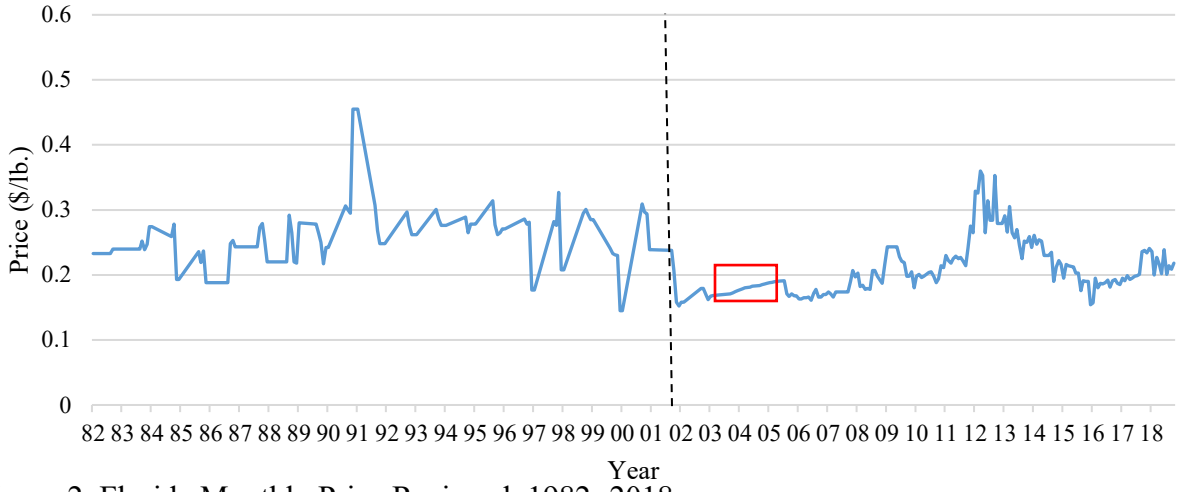


Figure 2. Florida Monthly Price Recieved, 1982- 2018

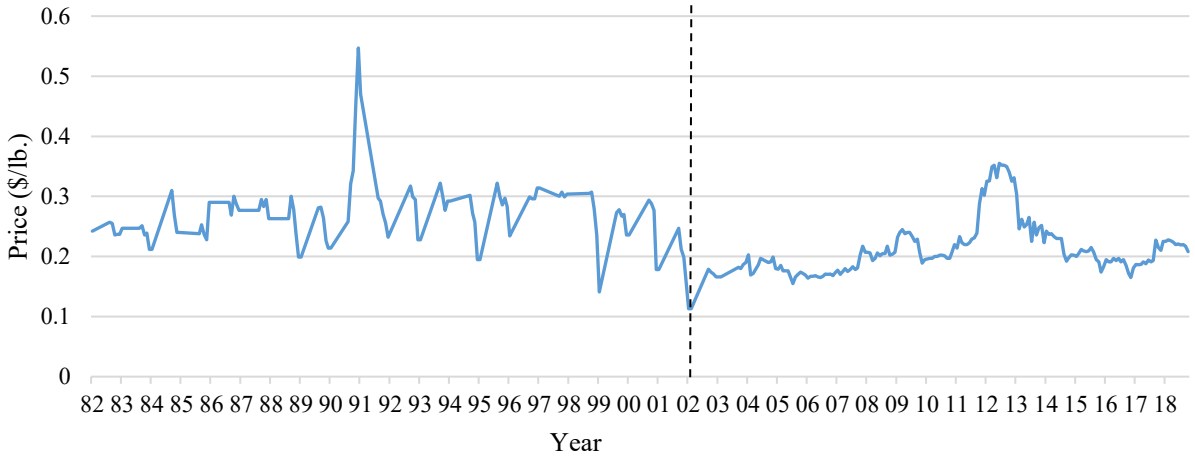


Figure 3. Georgia Monthly Peanut Price Recieved, 1982-2018

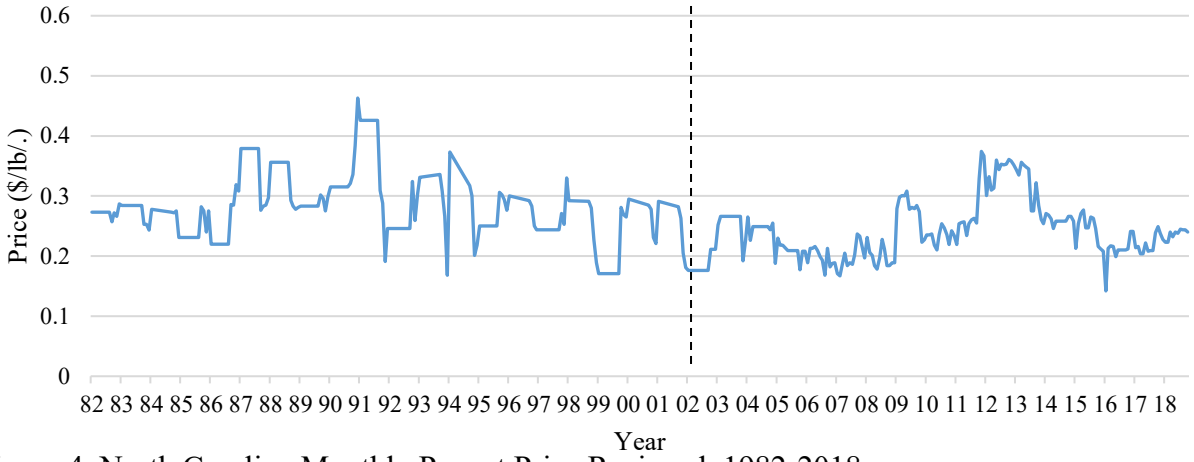


Figure 4. North Carolina Monthly Peanut Price Recieved, 1982-2018

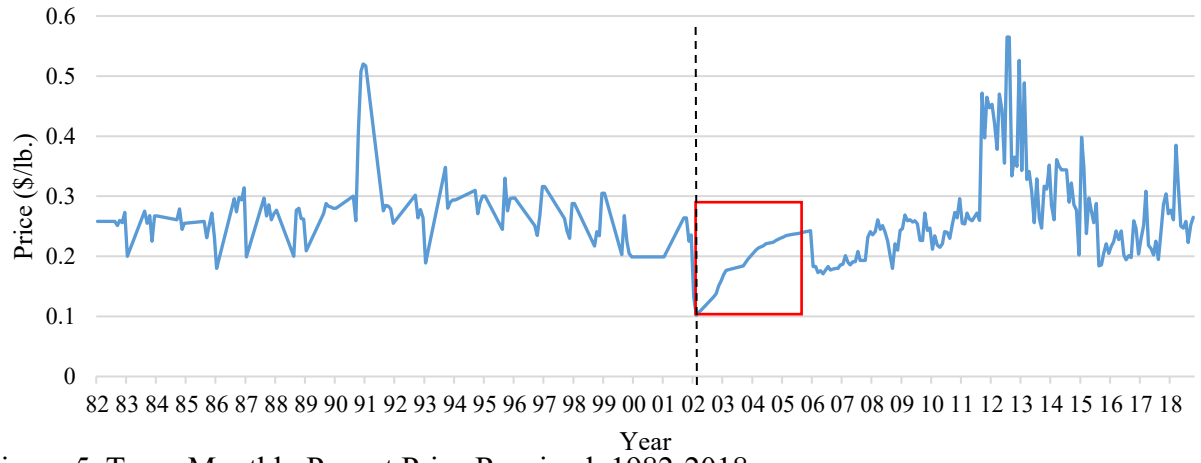


Figure 5. Texas Monthly Peanut Price Received, 1982-2018

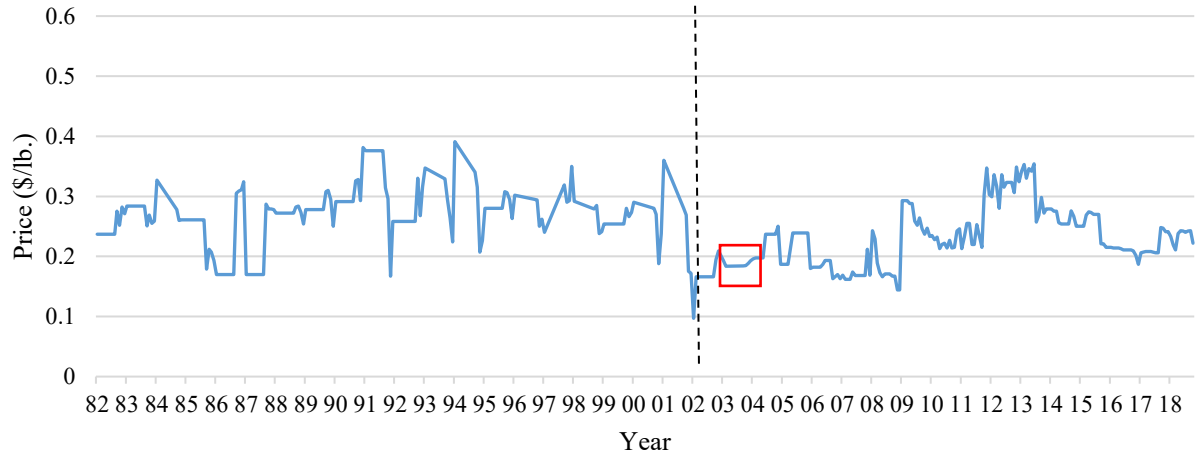


Figure 6. Virginia Monthly Peanut Price Received, 1982-2018

# CHAPTER III

# METHODOLOGY

This study estimates market integration and price discovery patterns among grower level peanut prices from Alabama, Florida, Georgia, North Carolina, Texas and Virginia over two time periods, 1982 to 2001 and 2002 to 2019. Patterns are estimated using causality structures identified through cutting-edge machine learning algorithms that are applied to the variance-covariance matrix of peanut prices from these states. Aforementioned causality structures are developed using Directed Acyclic Graphs (Pearl, 2009). The correlation between the current-time peanut prices and prices from the previous two periods (lag time one and lag time two are presented in Table 3 and Table 4.

Dharmasena, Bessler, and Capps (2016) and Kim and Dharmasena (2018) used Greedy Equivalence Search (GES) machine-learning algorithm in order develop causality structures pertains to food environment complex and U.S. pecan market integration, respectively. GES is operationalized through TETRAD statistical package, which searches causal models with artificial intelligence and DAG. According to Dharmasena, Bessler, and Capps (2016) and Kim and Dharmasena (2018), GES finds the optimal causal structures in order to minimize a Bayesian Information Criteria (BIC). Chickering (2002) explains the BIC approximation from Schwarz Loss Function and the assumptions underlying GES. The working of GES algorithm is based on three assumptions. They are causal sufficiency condition, causal faithfulness condition and causal Markov condition. These conditions are explained in Dharmasena, Bessler, and Capps (2016).

Table 3. Correlation Matrix of Peanut Prices, 1982-2002

| | **AL(*t*)** | **FL(*t*)** | **GA(t)** | **NC(t)** | **TX(t)** | **VA(t)** | **AL(*t*-1)** | **FL(*t*-1)** | **GA(*t*-1)** | **NC(*t*-1)** | **TX(*t*-1)** | **VA(*t*-1)** | **AL(*t*-2)** | **FL(*t*-2)** | **GA(*t*-2)** | **NC(*t*-2)** | **TX(*t*-2)** | **VA(*t*-2)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AL(*t*)** | 0.0033 | | | | | | | | | | | | | | | | | |
| **FL(*t*)** | 0.0013 | 0.002 | | | | | | | | | | | | | | | | |
| **GA(t)** | 0.0021 | 0.0008 | 0.003 | | | | | | | | | | | | | | | |
| **NC(t)** | 0.0002 | 0.0001 | 0 | 0.0024 | | | | | | | | | | | | | | |
| **TX(t)** | 0.002 | 0.0008 | 0.0013 | 0.0001 | 0.003 | | | | | | | | | | | | | |
| **VA(t)** | 0.0001 | 0 | 0 | 0.0013 | 0.0001 | 0.0021 | | | | | | | | | | | | |
| **AL(*t*-1)** | 0.0016 | 0.0006 | 0.0006 | 0.0004 | 0.001 | 0.0002 | 0.0031 | | | | | | | | | | | |
| **FL(*t*-1)** | 0 | 0.001 | 0 | 0 | 0 | 0 | 0 | 0.0025 | | | | | | | | | | |
| **GA(*t*-1)** | 0.0016 | 0.0006 | 0.0019 | 0 | 0.001 | 0 | 0.0009 | 0 | 0.0028 | | | | | | | | | |
| **NC(*t*-1)** | 0.0001 | 0.0001 | 0 | 0.0013 | 0.0001 | 0.0007 | 0.0003 | 0 | 0 | 0.0023 | | | | | | | | |
| **TX(*t*-1)** | 0.0003 | 0.0001 | 0 | 0.0011 | 0.0002 | 0.0006 | 0.0007 | 0 | 0 | 0.0005 | 0.0032 | | | | | | | |
| **VA(*t*-1)** | 0 | 0.0003 | 0 | 0 | 0 | 0 | 0 | 0.0007 | 0 | 0 | 0 | 0.0021 | | | | | | |
| **AL(*t*-2)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0038 | | | | | |
| **FL(*t*-2)** | 0 | 0.0006 | 0 | 0 | 0 | 0 | 0 | 0.0016 | 0 | 0 | 0 | 0.001 | 0 | 0.0024 | | | | |
| **GA(*t*-2)** | 0.0013 | 0.0005 | 0.0013 | 0 | 0.0008 | 0 | 0.0014 | 0 | 0.0019 | 0 | 0 | 0 | 0 | 0 | 0.0028 | | | |
| **NC(*t*-2)** | 0 | 0 | 0 | 0.0006 | 0 | 0.0004 | 0 | 0 | 0 | 0.0013 | 0 | 0 | 0 | 0 | 0 | 0.0025 | | |
| **TX(*t*-2)** | 0.0005 | 0.0002 | 0 | 0.0009 | 0.0003 | 0.0005 | 0.0013 | 0 | 0 | 0.0008 | 0.0018 | 0 | 0 | 0 | 0 | 0 | 0.0031 | |
| **VA(*t*-2)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 4. Correlation Matrix of Peanut Prices, 2002-2018

| | AL | FL | GA | NC | TX | VA | ALt-1 | FLt-1 | GAt-1 | NCt-1 | TXt-1 | VAt-1 | ALt-2 | FLt-2 | GAt-2 | NCt-2 | TXt-2 | VAt-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | 0.0014 | | | | | | | | | | | | | | | | | |
| FL | 0.0009 | 0.001 | | | | | | | | | | | | | | | | |
| GA | 0.0015 | 0.0011 | 0.0018 | | | | | | | | | | | | | | | |
| NC | 0.0005 | 0.0004 | 0.0007 | 0.0013 | | | | | | | | | | | | | | |
| TX | 0.002 | 0.0015 | 0.0024 | 0.0009 | 0.0052 | | | | | | | | | | | | | |
| VA | 0.0003 | 0.0002 | 0.0003 | 0.0007 | 0.0005 | 0.0008 | | | | | | | | | | | | |
| ALt-1 | 0.0009 | 0.0006 | 0.0009 | 0.0003 | 0.0013 | 0.0002 | 0.0011 | | | | | | | | | | | |
| FLt-1 | 0.0004 | 0.0006 | 0.0005 | 0.0002 | 0.0008 | 0.0002 | 0.0003 | 0.0008 | | | | | | | | | | |
| GAt-1 | 0.0015 | 0.0011 | 0.0018 | 0.0007 | 0.0025 | 0.0003 | 0.001 | 0.0005 | 0.0019 | | | | | | | | | |
| NCt-1 | 0 | 0.0001 | 0 | 0.0011 | 0.0001 | 0.0006 | 0 | 0.0001 | 0 | 0.0017 | | | | | | | | |
| TXt-1 | 0.0015 | 0.0013 | 0.0019 | 0.0009 | 0.0032 | 0.0006 | 0.001 | 0.0008 | 0.0018 | 0.0003 | 0.0043 | | | | | | | |
| VAt-1 | 0 | 0.0001 | 0 | 0.0001 | 0.0001 | 0.0004 | 0 | 0.0001 | 0 | 0.0001 | 0.0003 | 0.0006 | | | | | | |
| ALt-2 | 0.0002 | 0 | 0 | 0 | 0 | 0 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0.0019 | | | | | |
| FLt-2 | 0 | 0.0003 | 0 | 0 | 0 | 0 | 0 | 0.0007 | 0 | 0 | 0 | 0 | 0 | 0.0016 | | | | |
| GAt-2 | 0.0015 | 0.0011 | 0.0018 | 0.0006 | 0.0025 | 0.0003 | 0.001 | 0.0006 | 0.0019 | 0 | 0.0019 | 0 | 0 | 0 | 0.002 | | | |
| NCt-2 | 0 | 0 | 0 | 0.001 | 0 | 0.0005 | 0 | 0 | 0 | 0.0016 | 0 | 0 | 0 | 0 | 0 | 0.0023 | | |
| TXt-2 | 0.0001 | 0.0004 | 0.0002 | 0.0006 | 0.0007 | 0.0008 | 0 | 0.0007 | 0 | 0.0009 | 0.0021 | 0.001 | 0 | 0 | 0 | 0 | 0.0062 | |
| VAt-2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# CHAPTER IV

# RESULTS

Figure 7 is the Directed Acyclic Graph of peanut prices, from 1992 to 2001, in 6 states with two lags of price series. The marginal effects are denoted on the edges between variables while the mean values are denoted in green on the lower right side of the state. As explained by Kim and Dharmasena (2018), "Each edge with direction determines the predictor and predicted variables in the regression model. Each number on an edge is the estimated slope coefficient of the predictor variable when arrow-received variable (dependent variable) is regressed on every causing variable (independent variable)." In addition, Table 5 exhibits the resulting coefficients and p-values associated with Figure 7. One notable observation is that all of the coefficients are significant at the 1% level or less. This analysis provides valuable information regarding how prices are related among these peanut producing states.

Current period prices in Georgia are positively influenced by prices from the previous two time periods of Georgia. Current prices in Georgia and the previous periods' price in Alabama impact the current price in Alabama. These current prices in Alabama are the primary factor influencing current prices in Texas, which is a price sink. However, there are additional prices such as the current, previous, and two period previous prices in Georgia, that indirectly influence Texas prices through a causal chain. Texas prices from two periods previous also indirectly affects the current price in Alabama and therefore also indirectly influences current prices in Texas and Florida, this creates causal chains. Virginia and Florida are also price sinks, with Virginia being influenced by North Carolina current prices and Florida receiving prices from previous period prices in Florida (FLt-1) and current price in Alabama. North Carolina's

current prices are influenced by the previous prices in North Carolina (NCt-1) and Texas (TXt-1). In addition, North Carolina's current price is also indirectly influenced by the prices two periods ago in Texas (TXt-2) and North Carolina (NCt-2), these causal chain relationships are illustrated in Figure 7.

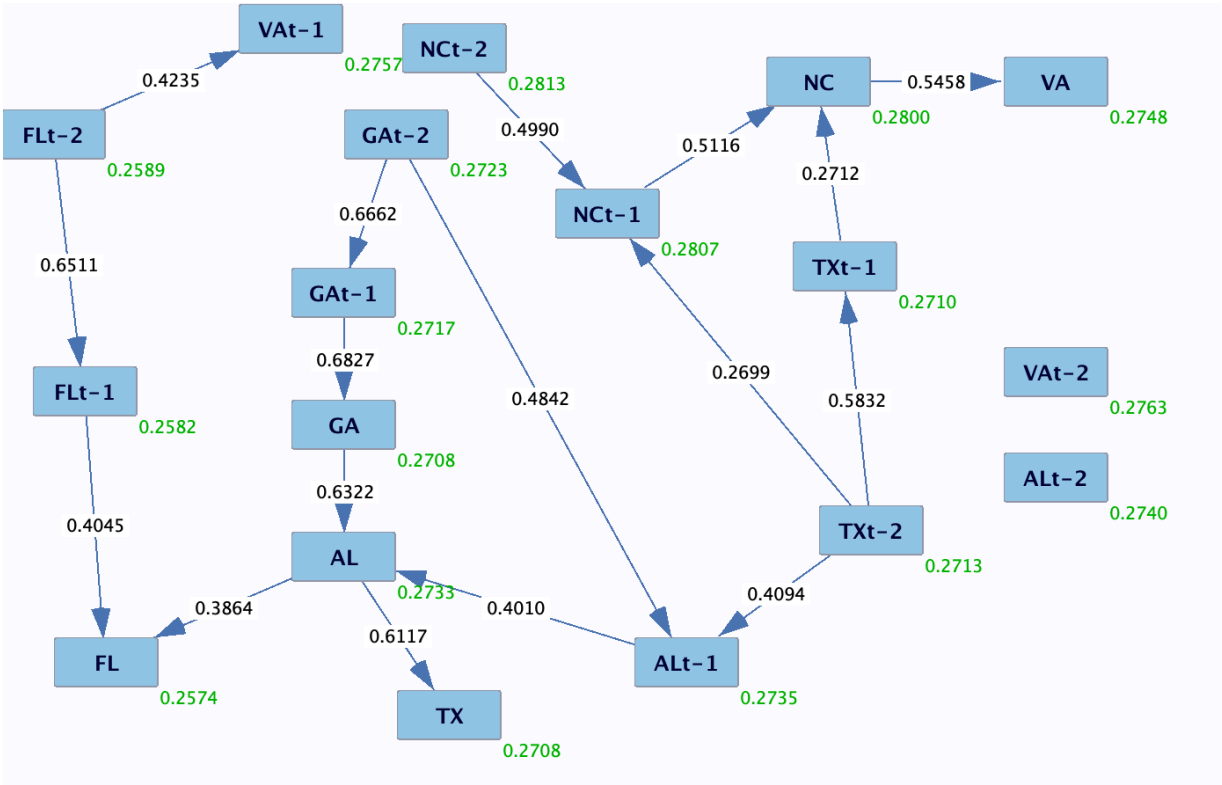

Figure 7. Directed Acyclic Graph (DAG) of Peanut Prices, 1982-2001

Table 5. Parameter Estimates for Each Edge, 1982-2001

| From | To | Edge Coefficient | p-value |
|---|---|---|---|
| GA | AL | **0.6322** | 0.000 |
| ALt-1 | AL | **0.401** | 0.000 |
| NC | VA | **0.5458** | 0.000 |
| FLt-1 | FL | **0.4045** | 0.000 |
| NCt-1 | NC | **0.5116** | 0.000 |
| FLt-2 | VAt-1 | **0.4235** | 0.000 |
| TXt-2 | ALt-1 | **0.4094** | 0.0001 |
| TXt-2 | TXt-1 | **0.5832** | 0.000 |
| TXt-2 | NCt-1 | **0.2699** | 0.0003 |
| TXt-1 | NC | **0.2712** | 0.0003 |
| GAt-2 | GAt-1 | **0.6662** | 0.000 |
| NCt-2 | NCt-1 | **0.499** | 0.000 |
| GAt-1 | GA | **0.6827** | 0.000 |
| AL | TX | **0.6117** | 0.000 |
| AL | FL | **0.3864** | 0.000 |
| GAt-2 | ALt-1 | **0.4842** | 0.000 |
| FLt-2 | FLt-1 | **0.6511** | 0.000 |

Note: Significance level considered is p-value 0.05 AL=Alabama, FL=Florida, GA=Georgia, NC=North Carolina, TX=Texas and VA=Virginia. ALt-1, FLt-1, GAt-1, NCt-1, TXt-1, VAt-1, ALt-2, FLt-2, GAt-2, NCt-2, TXt-2, and VAt-2 represent peanut prices received by growers in time periods t and t-1 in Alabama (AL), Florida (FL), Georgia (GA), North Carolina (NC), Texas (TX), and Virginia (VA), respectively.

The directed acyclic graph of peanut prices from 2002 to 2018, after the marketing quota system was discontinued, is shown in Figure 8. The coefficients and p-values are also shown in Table 6, with all the values being statistically significant at the 1% level. Just as in the DAG from 1982 to 2001, Texas is a price sink; however, current Texas prices are now influenced by the previous period's prices in Texas and Georgia. The current periods in Alabama, Florida, and Virginia are also price sinks. Current prices in Alabama are influenced by its previous periods price (ALt-1) and the current price in Georgia. Prices in Georgia from two periods ago (GAt-2) also impacts current Alabama prices by influencing prices in Texas (TXt-1) and Alabama (ALt-1), which then directly and indirectly influence the current price in Alabama. Although Florida's

previous price and Georgia's current prices are the only factors directly influencing the current price in Florida, prices from two periods ago in Texas, Georgia, and Florida all indirectly influence the price through various causal chains.

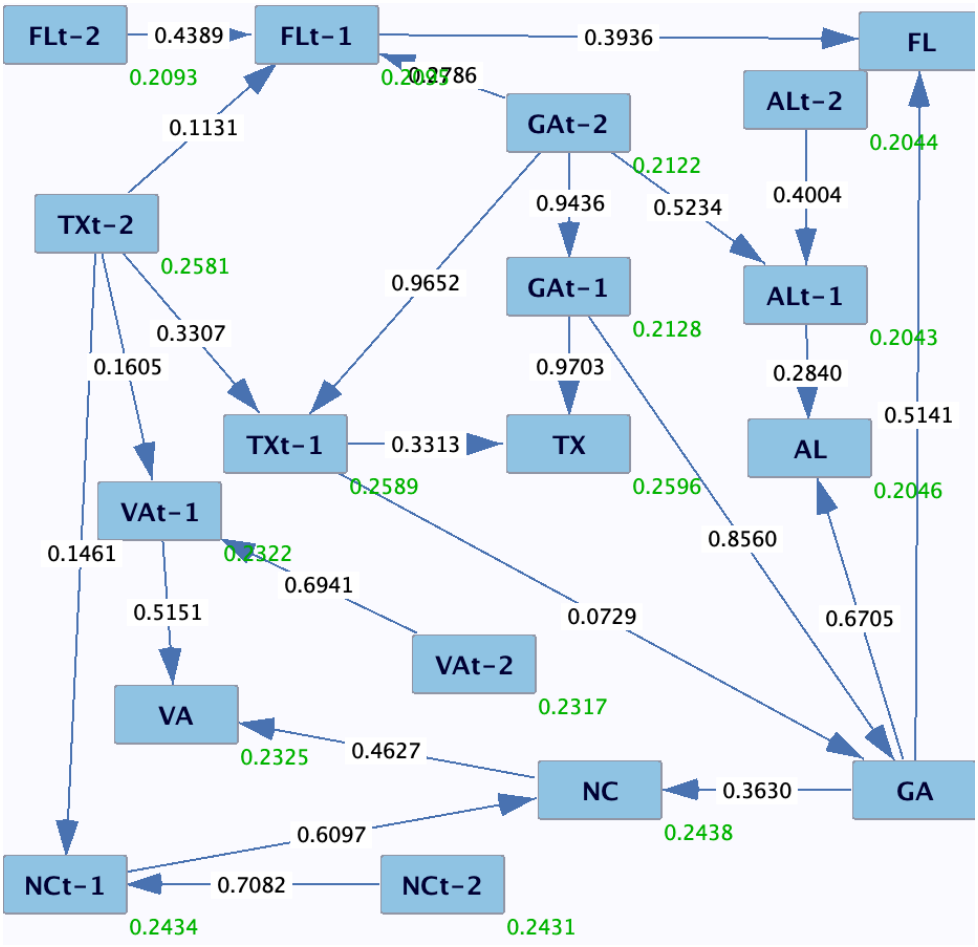


Figure 8. Directed Acyclic Graph (DAG) of Peanut Prices, 2002-2018

These chains are shown in Figure 8. The current price in Virginia receives signals from the current price in North Carolina and the previous price in Virginia. The price in Texas and Georgia from previous periods also indirectly influences the price in Virginia. North Carolina's current price receives signals from its price during the previous period and the current price in Georgia. The current price in Georgia is influenced by the prices from the two consecutive

previous periods in Georgia and Texas. This results in previous Texas and Georgia prices influencing the current North Carolina price. Ultimately, the previous prices from two periods ago in Texas (TXt-2) and Georgia (GAt-2) indirectly influence the current prices in all states. On the contrary, prices from two periods ago in Virginia (VAt-2), Florida (FLt-2), and Alabama (ALt-2) only influence their respective current price. North Carolina's price from two periods ago (NCt-2) indirectly influences its current price and, more indirectly, Virginia's current price.

Table 6. Parameter Estimates for Each Edge, period 2002-2018

| From | To | Edge Coefficient | p-value |
|---|---|---|---|
| GAt-2 | ALt-1 | **0.5234** | 0.000 |
| TXt-2 | TXt-1 | **0.3307** | 0.000 |
| NCt-2 | NCt-1 | **0.7082** | 0.000 |
| TXt-2 | VAt-1 | **0.1605** | 0.000 |
| GAt-1 | TX | **0.9703** | 0.000 |
| FLt-1 | FL | **0.3936** | 0.000 |
| NC | VA | **0.4627** | 0.000 |
| GA | FL | **0.5141** | 0.000 |
| GAt-2 | TXt-1 | **0.9652** | 0.000 |
| ALt-1 | AL | **0.284** | 0.000 |
| TXt-2 | FLt-1 | **0.1131** | 0.000 |
| NCt-1 | NC | **0.6097** | 0.000 |
| VAt-2 | VAt-1 | **0.6941** | 0.000 |
| TXt-1 | TX | **0.3313** | 0.000 |
| GAt-1 | GA | **0.856** | 0.000 |
| GAt-2 | GAt-1 | **0.9436** | 0.000 |
| FLt-2 | FLt-1 | **0.4389** | 0.000 |
| VAt-1 | VA | **0.5151** | 0.000 |
| GAt-2 | FLt-1 | **0.2786** | 0.0001 |
| GA | AL | **0.6705** | 0.000 |
| TXt-1 | GA | **0.0729** | 0.0001 |
| GA | NC | **0.363** | 0.000 |
| TXt-2 | NCt-1 | **0.1461** | 0.000 |
| ALt-2 | ALt-1 | **0.4004** | 0.000 |

Note: Significance level considered is p-value 0.05 AL=Alabama, FL=Florida, GA=Georgia, NC=North Carolina, TX=Texas and VA=Virginia, ALt-1, FLt-1, GAt-1, NCt-1, TXt-1, VAt-1, ALt-2, FLt-2, GAt-2, NCt-2, TXt-2, and VAt-2 represent peanut prices received by growers in time periods t and t-1 in Alabama (AL), Florida (FL), Georgia (GA), North Carolina (NC), Texas (TX), and Virginia (VA), respectively.

# CHAPTER IV

# CONCLUSIONS AND IMPLICATIONS

In conclusion, Georgia and Texas are price leaders with their past and current prices influencing current prices in the majority of other states in both time periods studied. Current and previous periods prices in Georgia are strictly exogenous in the first time period, 1982 to 2001. In the time period, 2002 to 2018, previous period prices in Georgia are also strictly exogenous while the current price is weakly exogenous (GA causes prices of AL, FL and NC and caused by prices from GA and TX past one period). In addition, the price from the preceding periods is also a major determinant in current period prices for almost all the states. During the post 2002 period, the current price in all 6 states studied are directly influenced by their price in the previous period. Prior to 2002, current prices in Florida, Alabama, Georgia, and North Carolina are directly influenced by their respective prices from the preceding period; however, prices in Texas and Virginia are not influenced by their price from the previous period.

These price integration patterns among peanut prices in Alabama, Florida, Georgia, North Carolina, and Texas from 1982 to 2001 and from 2002 to 2018, were developed using machine-learning algorithms and directed acyclic graphs. The resulting knowledge of direct and indirect causal relationships amongst peanut prices in these states is expected to be useful to peanut producers and marketers, as well as government policy makers to design national/state level peanut marketing programs.

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